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TEST RESULTS OF PHASE 3 LEVEL A SUITS TO CHALLENGE BY CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND SIMULANTS: EXECUTIVE SUMMARY

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Swatches from four commercially available Level A protective suits were challenged with liquid droplets of sarin (GB) and mustard (HD) using modifications of the static diffusion procedure described in TOP 8-2-501. The cumulative mass of each agent that permeated each swatch was determined over time, and the results for all swatches were used to determine a weighted-average cumulative mass for each suit. From these data, a physiologically-derived breakthrough time was calculated for each suit for the purposes of comparison. In addition, intact suits were challenged with corn-oil aerosol to simulate a biological or chemical aerosol. Protection factors were determined for each suit.

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Executive Summary

As part of the Domestic Preparedness Program, four Occupational Safety and Health Administration Level A* suit designs were tested to assess their capability to protect in a chemical warfare (CW) agent or biological agent environment. Swatches of material from each suit design were tested for resistance to permeation by sarin (GB) and mustard (HD). From these data, the authors calculated the estimated time it would take to permeate the suit with sufficient agent to cause physiological effects in a person wearing the suit. Each suit design was also tested for its protection factor in an aerosol environment (aerosolized corn oil, which may be representative of a chemical or biological agent, was used). Protection factor is defined as the ratio between the challenge concentration outside the suit and the measured concentration inside the suit. The tests are described, and the calculated physiologically-derived breakthrough times and protection factors (PF) are presented.

* Level A protection consists of a completely encapsulating, gas/vapor proof chemical resistant suit; a self-contained breathing apparatus (SCBA) or positive-pressure supplied-air respirator with escape SCBA, chemical resistant gloves and boots.

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Preface

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U. S. Army Edgewood Chemical Biological Center (ECBC) Homeland Defense Business Unit. This work was started in March 2000 and completed in September 2000.

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TEST RESULTS OF PHASE 3 LEVEL A SUITS TO CHALLENGE BY CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND SIMULANTS: EXECUTIVE SUMMARY

1. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1996), directing the Department of Defense (DoD) to assist other federal, state, and local agencies in enhancing preparedness for terrorist attacks using weapons of mass destruction. The DoD responded by forming the Domestic Preparedness Program that same year. One of the objectives of the Domestic Preparedness Program is to enhance federal, state and local emergency and hazardous material (HAZMAT) response to nuclear, biological and chemical (NBC) terrorism incidents. As part of an effective response, emergency and HAZMAT personnel who are responding to an incident will use personal protective equipment (PPE) to protect them from exposure to chemical agents or biological agents. The specific PPE that would be used by these federal, state, and local emergency and HAZMAT personnel would depend upon the situation encountered and what PPE is held in inventory. In some cases, Level A protective suits may be required to enter a contaminated or potentially contaminated area. Level A suits provide the greatest level of skin, respiratory, and eye protection. Air is supplied by a pressure-demand full-facepiece self-contained breathing apparatus (SCBA) or supplied-air lines. Recognizing this need, the U.S. Army Soldier and Biological Chemical Command (SBCCOM) established a program to test some of the Level A suit designs, using CW agents and test procedures developed for assessment of military-issue CW protective equipment. A detailed technical report was to be generated for each suit design tested, and a summary report was prepared that presented the essential results for all the suits in a single document. Because those reports are rather lengthy and technical, this report was prepared. This report is an overview of the results of the evaluation and this information is intended for emergency responders as an aid in evaluating Level A suits when they choose to include military chemical and biological agent protection as a criterion. This information supplements data and information provided by the suits' manufacturers. The suits were tested in new, as-received condition. The effects of aging, temperature extremes, laundering, and other factors are beyond the intended scope of this test program. These tests are conducted to assess percutaneous (i.e., skin) protection[1] only.

Each suit was examined in two different ways, called swatch tests and aerosol tests. In the swatch tests, sample swatches were cut from selected areas (the basic suit material, a seam, and at least four other areas that were dependent upon the suit configuration) of each suit design. These swatches were then exposed to the chemical agents mustard (HD) and sarin (GB), and the passage of agent through them measured. Sarin is a non-persistent (volatile) nerve agent, and HD is a persistent blister agent. In the aerosol tests, each suit design was donned by volunteer testers, who carried out a prescribed sequence of movements inside a test chamber containing a controlled aerosol of corn oil that is a non-toxic simulant for chemical and

[1] Inhalation and ocular protection are typically provided by the use of a SCBA or air-supplied respirator that covers the eyes, nose and mouth.

biological agent aerosols. Instrumentation continuously measured the concentration of simulant inside the suit. Each of these tests examined different aspects of the protection provided by the suits.

Protection provided by a suit system may vary from one unit to another, partly because variations in body size and shape affect the suit's fit; and from one occasion to another, partly because of unavoidable differences in the execution of the prescribed movements. For these reasons, each suit system design was subjected to multiple test repetitions, using a number of different sample suits, volunteer testers, and occasions.

2. LIQUID CHALLENGE/VAPOR PERMEATION TEST (SWATCH TEST)

Three swatches were taken from a minimum of six different areas of the suit or ensemble – at least 18 total swatches per suit design for GB and at least 18 more for HD. The swatches were placed in a test fixture and a predetermined (10 g/m^2) liquid agent challenge, GB or HD, was applied to the top surface of each swatch, and the fixture sealed. Periodically, over 24 hr, gas samples were taken from below the swatches. The amount of agent vapor that permeated the test swatch at each sampling time was measured using a highly sensitive, accurate, miniaturized gas chromatograph and sampling system known as MINICAMS™ (OI Analytical, CMS Field Products Group, Birmingham, AL).

The cumulative mass of agent vapor, which has permeated each of the swatches at each sampling time, divided by the area of the swatch, was defined as the permeation, M_f.

The permeation for each suit design tested was compared with other suit designs. Normally, continuous exposure to chemical agent would not exceed 8 hr (480 min) because of heat stress and fatigue.

An average cumulative permeation value (M_f) for each suit design and agent combination was calculated by averaging the M_f values for the 18 swatches.

The permeation will typically vary greatly from one area of a suit to the next, because of differences in materials and thickness. A composite average permeation value was calculated by assigning a weighting factor to the permeation value for each swatch, roughly proportional to the actual area on the suit system that the swatch represents. This resulted in a calculated overall permeation for each suit design.

Mustard vapor can produce skin irritation (erythema) at dosages (product of concentration and exposure time) of approximately 100 $mg\text{-}min/m^3$. Sarin vapor can produce incapacitation at dosages of approximately 8000 $mg\text{-}min/m^3$. These dosages were set as limits, and the average time to reach each of the limits was calculated using the weighted values of the swatch test results, and it was designated the "physiologically-derived breakthrough time" for the suit, under the specific test conditions.

The calculated breakthrough times from all the suit swatches were collected and presented in Table 1.

Table 1. Swatch Test Results for Suits

Test Item	Physiologically-derived breakthrough time (minutes)	
	Incapacitation	Erythema
	GB	HD
Lakeland Deluxe Level A 10640	>522	177
Lakeland Economy Level A 10660	128	124
Mar Mac Commander 9400FB	597	216
Giat UNISCAPH Gas Tight Suit	416	180

3. SYSTEM TEST (AEROSOL SIMULANT)

This test measured the leakage of a challenge corn-oil aerosol (physical simulant for biological or chemical aerosol) into a suit ensemble while people were wearing ensembles of different sizes. Volunteers dressed in Level A suits with self-contained breathing apparatus (SCBA) entered a chamber with aerosol simulant. Instrumentation measured any aerosol leakage (presumed to be penetration) into the suit through gaps between ensemble components. During the test, the people in the suits performed standardized movements. See Tables 2 and 3.

Eight suits of each design were worn by 12 volunteers on each of two days (not necessarily the same 12 on both days), for a total of at least 24 trials for each suit design. However, because it was not possible to retain the same 12 volunteers throughout the entire course of testing, this variable (the differences among wearers) was not held constant across all suit designs.

Table 2. Phase 1 Aerosol Test Exercise Routine

Test	Description of Exercise
Pre-Operational – Each exercise performed for 1 min.	1) Standing still, normal breathing
	2) Bending forward and touching toes
	3) Jogging in place
	4) Raising arms above head and looking upward
	5) Bending knees and squatting
	6) Crawling on hands and knees
	7) Torso twists with hands folded on chest
	8) Standing still, normal breathing

Table 3. Phase 2 Aerosol Test Exercise Routine

Test	Description of Exercise
Operational – Each exercise performed for 4 min.	1) Climb step ladder
	2) Move 3 lb boxes from table to floor
	3) Rest
	4) Roll walls and ceiling
	5) Bag clothes
	6) Rest
	7) Loosen bolts
	8) Move 3 lb boxes from floor to table

From this test a protection factor (PF) is derived. In simplest terms, PF is a measure of the challenge concentration outside the suit divided by the concentration inside the suit ensemble. For example, if the concentration of aerosol inside the suit ensemble is found to be 1/10th the value of the average concentration outside the suit ensemble, the PF is equal to 10.

Samples of aerosol are taken continuously at the neck area and upper arm within the suit, and their concentrations are measured by laser photometry, recorded in a computer file, and displayed continuously on a computer monitor. These sampling locations were selected as being the most likely locations for aerosol leakage to occur. Therefore the PF is thought to be the worst case estimation. The PF data are presented based upon predetermined PF pass levels, ranging from 2 to 100,000 (i.e., at each pass level the number of failing and passing suits is recorded). The higher the percentage of test runs that pass at a given PF, the greater the probability that the suit will provide that level of protection in use. The results are given in Table 4.

Table 4. Summary of Overall Aerosol Test Results

Test Item	Percentage of Test Runs Where PF Met Each Hypothetical PF Threshold Value			Exercise Phase
	500	5000	10000	
Lakeland Deluxe Level A 10640	86	16	2	Pre-Operational
	83	38	24	Operational
Lakeland Economy Level A 10660	100	68	25	Pre-Operational
	95	95	86	Operational
Mar Mac Commander 9400FB	100	62	26	Pre-Operational
	100	77	36	Operational
Giat UNISCAPH Gas Tight Suit	87	0	0	Pre-Operational
	74	13	4	Operational

4. CONCLUSIONS AND RECOMMENDATIONS

The test data reveals that the OSHA Level A suits tested can protect the wearers from CW agents in liquid, vapor or aerosol form. Breakthrough times should not be interpreted as the time that a suit can be safely worn, either for HD or GB. Breakthrough times should only be used to compare suit materials. The duration of protection provided by each suit design will vary considerably according to how well the suit is fitted to the individual, the body motions required, and the concentration and distribution of the chemical agent in the environment.